Wastewater Treatment Plant
Operator Certification Training
Instructor Guide

Module 18
The Activated Sludge Process
Part IV

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

A Note to the Instructor

Dear Instructor:

The primary purpose of this course, *Module 18: The Activated Sludge Process – Part IV*, is to provide an overview of the removal of nitrogen and phosphorus from wastewater as well as an overview of the various mechanisms used to accomplish these tasks. This module has been designed to be completed in approximately 4 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topically outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by DEP.

Web site URLs and other references are subject to change, and it is the training sponsor's responsibility to keep such references up to date.

Delivery methods to be used for this course include:

- Lecture
- Quizzes
- Discussion Questions

To present this module, you will need the following materials:

- One workbook per participant
- Extra pencils
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Flip Chart
- Markers

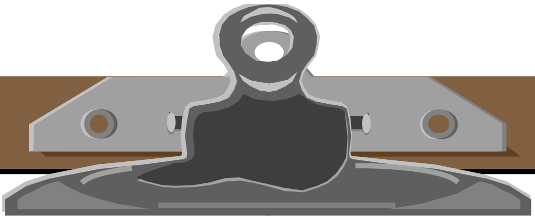
Icons to become familiar with include:

Participant Workbook		Instructor Guide	
✓	Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.	
📖	Case Study	Ans:	Answer to exercise, case study, discussion, question, etc.
❓	Discussion Question	🖼	PowerPoint Slide
🧮	Calculation(s)		
📝	Quiz	📽	Overhead
📕	Key Definition(s)	📋	Flip Chart
🔑	Key Point(s)	💬	Suggested "Script"

Instructor text that is meant to be general instructions for the instructor is designated by being written in script font and enclosed in brackets. For example:

[*Ask participants if they have any questions on how to read the table. Answer any questions participants may have about how to read the table.*]

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.



PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	**Press**
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

[Display Slide 1—Module 18: The Activated Sludge Process – Part IV.

Welcome participants to "Module 18 – The Activated Sludge Process –Part IV." Indicate the primary purpose of this course is to provide an overview of the removal of nitrogen and phosphorus from wastewater as well as an overview of the various mechanisms used to accomplish these tasks. State that this module also provides an overview of the treatment of combined municipal and industrial wastewater.

Introduce yourself.

Provide a brief overview of the module.]

This module contains 4 units. On page i, you will see the topical outline for **Unit 1 – Nitrification and Denitrification** and **Unit 2 – Biological Phosphorus Removal.**

[Briefly review outline.]

If you turn the page, you will see the topical outline for **Unit 3 – Combined Nitrogen and Phosphorus Removal or Biological Nutrient Removal** (BNR) and **Unit 4 – Treatment of Combined Municipal and Industrial Wastewater.**

[Continue to briefly review outline.]

If you turn the page, you will find the remainder of the outline.

UNIT 1: 115 minutes

[Display Slide 2—Unit 1: Nitrification and Denitrification.]

At the end of this unit, you should be able to:

- Explain what nitrogen is and why it needs to be removed from wastewater.
- List five forms of nitrogen.
- Describe nitrogen's effects on receiving water.
- List the various types of nitrogen removal mechanisms and explain how they work.

[Display Slide 3—Unit 1: Nitrification and Denitrification.]

The next learning objective for this unit is:

- In terms of biological nitrification:
    - List the types of suspended growth reactors used.
    - Describe the mixing requirements for suspended growth reactors.
    - List the types of aeration systems used in suspended growth reactors.
    - List and explain the operating parameters required for nitrification in a suspended growth reactor.

[Display Slide 4—Unit 1: Nitrification and Denitrification.]

The final learning objective for the unit is:

- In terms of biological denitrification:
    - List the types of suspended growth reactors used.
    - List and explain the operating parameters required for denitrification in a suspended growth reactor.

NITROGEN AND NITROGEN REMOVAL MECHANISMS: 35 minutes

We will begin the module and this unit by discussing nitrogen and nitrogen removal mechanisms.

Nitrogen

[Review the definition of inorganic nitrogen in the workbook.]

There are five forms of nitrogen typically present in wastewater and natural water systems: ammonium, ammonia, nitrite, nitrate and organic-N. Let's begin by talking about ammonium and ammonia. We will discuss these two forms together since they are closely related.

Ammonium and Ammonia

[Review the first bullet item in the workbook and then share the following:]

On the left of this equation, we see ammonium ion, which is the NH_4^+. On the right side of the equation we have ammonia gas, or NH_3, and hydrogen ion, H^+.

[Review the remaining bullet items in the workbook.

Display Slide 5—Effect of pH and Temperature on Equilibrium between Ammonium and Ammonia.]

This graph shows that when the pH begins to rise above 7, the amount of ammonia gas increases until almost the entire ammonium ion is converted to ammonia gas at pH of 10.8 to 11.5. If you look at the left side of the graph, you will see the percentage of NH_3 increases, while on the right side of the graph, you will see the percentage of NH_4^+ decreases.
The lower the pH (i.e. 6) the more H^+ ions that are present in solution that will react with the NH_3 to become NH_4^+.

[Review remaining bullet item in the workbook.]

Nitrite

💬 Nitrite is the next form of nitrogen we will discuss.

[Review the information in the workbook including the definition for oxidation.]

Nitrate

💬 The next form of nitrogen is nitrate.

[Review the information in the workbook.]

Organic-N

💬 Organic nitrogen, or Organic-N, is yet another form of nitrogen found in wastewater.

[Review the information in the workbook.]

Nitrogen's Effect on Receiving Waters

💬 Now that we are familiar with some different types of nitrogen, we need to discuss how nitrogen affects receiving waters.

[Review the information in the workbook.]

Ammonia Toxicity

Nitrogen can adversely affect receiving waters and aquatic life through ammonia toxicity.

[Review the information in the workbook.]

Oxygen Depletion after Algae/Plant Die-off

The presence of nitrogen in receiving waters can also deplete the oxygen level.

[Review the information in the workbook.]

Note that phosphorus is typically the limiting nutrient for algae growth, so excess nitrogen discharges in the presence of limiting phosphorus concentrations will not likely result in algal blooms.

Nitrate in Groundwater

Another effect of nitrogen on receiving waters is the presence of nitrate in groundwater.

[Review the information in the workbook.]

Chloramines from Disinfection

The presence of chloramines is another effect of nitrogen.

[Review the definition of chloramines in the workbook.

Review the information in the workbook.]

Nitrogen Removal Mechanisms

Display Slide 6—Nitrogen Removal Mechanisms.]

As you can see, the presence of nitrogen in wastewater can be harmful. Consequently, it is necessary to remove nitrogen from wastewater. We will now begin discussing several different nitrogen removal mechanisms. Although there are quite a few nitrogen removal mechanisms, we will focus on seven of them: biological nitrification, biological denitrification, living systems, land application, ammonia stripping, breakpoint chlorination and ion exchange. Each of these removal mechanisms can be classified as biological, physical or chemical.

Take a look at Table 1.1 in your workbook. This table shows the efficiency of each nitrogen removal mechanism. The table also tells you if a removal mechanism is a biological, physical or chemical process.

[Have the class underline the following nitrogen removal treatment processes on Table 1.1:

- *Denitrification*
- *Nitrification*
- *Breakpoint chlorination*
- *Selective ion exchange*
- *Air stripping*

These are 5 of the 7 process that will be discussed. The other 2 are:

- *Living systems*
- *Land application]*

Biological Nitrification

The first removal mechanism we will discuss is biological nitrification.

[Review the definition of biological nitrification in the workbook.]

Referring back to Table 1.1, we see that biological nitrification is classified as a biological process and it will remove 5-20% of total nitrogen. Nitrification will be discussed in greater detail, later in this unit.

[Review the information in the workbook.]

Biological Denitrification

Our next removal mechanism is biological denitrification, which is also a biological process. This mechanism will remove 70-95% of total nitrogen, which is significantly more than what is removed via nitrification alone. Biological denitrification will also be discussed in further detail, later in Unit 1.

[Review the definition of biological denitrification.

Review the information in the workbook.]

Ammonia Stripping

The next nitrogen removal mechanism is ammonia stripping, which is a physical process.

[Review the definition of ammonia stripping in the workbook.

Review the information in the workbook.]

Breakpoint Chlorination

Breakpoint chlorination, our next removal mechanism, is a chemical process.

[Review the definition of breakpoint chlorination.

Review the information in the workbook.]

Ion Exchange

Another chemical removal mechanism is ion exchange.

[Review the definition of ion exchange in the workbook.

Review the information in the workbook.]

One of the advantages of using ion exchange for nitrogen removal is that it does not generate a nitrogen-bearing waste stream requiring further treatment or disposal. The disadvantages are that it requires extensive pretreatment, such as multimedia and carbon filtration, the resins may have a limited useable life, and the regeneration systems are often complicated.

Land Application

Land application, another biological process, is the next nitrogen removal mechanism we will discuss.

[Review the definition of overland flow systems in the workbook.]

Living Systems

The final nitrogen removal mechanism we will learn about is living systems, which is another biological process.

[Review the information in the workbook.]

Display Slide 7—Review Exercise.] Solicit answers from the students.

✓ Review Exercise

1. List the five types of nitrogen.

Ans: Ammonium, Ammonia, Nitrite, Nitrate and Organic-N.

2. List seven nitrogen removal mechanisms.

Ans: Biological nitrification, biological denitrification, living systems, land application, ammonia stripping, breakpoint chlorination and ion exchange.

BIOLOGICAL NITRIFICATION: 30 minutes

Now that we have looked at seven different nitrogen removal mechanisms, we are going to learn about biological nitrification and denitrification in more detail, beginning with biological nitrification. Biological nitrification can be accomplished in either a suspended growth reactor or an attached growth reactor, such as trickling filters or rotating biological contactors (RBCs). During this training module we will only being discussing biological nitrification using suspended growth reactors.

If you have an attached growth reactor at your activated sludge treatment facility that is used for nitrification/denitrification you can learn more about these treatment units at the training courses that are specific to trickling filters and RBCs.

Suspended Growth Reactors

[Review the information in the workbook.

Display Slide 8—Single-Stage and Separate-Stage.]

The top of this illustration shows the single-stage process. As you can see, there is only one nitrification tank. The bottom half of the illustration shows the separate-stage process. In this process, you can see that BOD removal occurs in the aeration tank and nitrification occurs in a separate tank. The separate-stage process provides more process flexibility and reliability than the single-stage process. The carbonaceous oxidation and nitrification stages in a separate-stage process can be operated independently. The carbonaceous oxidation stage provides a certain level of protection for the nitrification stage in that it can oxidize organics that are potentially toxic to the nitrifying bacteria before the bacteria reach the nitrification stage.

Types of Suspended Growth Reactors

There are six types of suspended growth reactors: conventional or plug flow, complete mix, contact stabilization, extended aeration, step-feed and batch aerators.

[Review the information in the workbook.]

Conventional or Plug Flow

[Review the information in the workbook.]

Complete Mix

[Review the information in the workbook.]

Contact Stabilization

[Review the information in the workbook.]

Extended Aeration

[Review the information in the workbook.]

Step-Feed

[Review the information in the workbook.]

Batch Reactors

[Review the information in the workbook.]

Mixing Requirements

In order to prevent solids from settling on the bottom of the aeration basin, each suspended growth reactor has certain mixing requirements. Your workbook contains some information about the specific mixing requirements for different types of reactors. We will not review that information in detail now.

Types of Aeration Systems

[Review the information in the workbook.]

Operating Parameters to be Monitored for Nitrification

Next we will discuss some of the operating parameters associated with nitrification. The parameters we will discuss are MLSS/MLVSS, pH, alkalinity, temperature, dissolved oxygen, MCRT, hydraulic retention time, BOD_5/TKN Ratio and BOD:N:P Ratio. Table 1.2 is provided for your reference. It shows some of the typical values for some of the operating parameters.

MLSS/MLVSS

The first parameter we will discuss is the mixed liquor volatile suspended solids, or, MLVSS.

[Review the definitions of MLSS and MLVSS in the workbook.

[Review the information in the workbook.]

pH

[Display Slide 9—The Effect of pH on the Rate of Nitrification.]

This slide shows the relationship between pH and the rate of nitrification. As this graph indicates, the rate of nitrification is maximized between the pH range of 7.8 to 8.2 at a temperature of 20°C.

Alkalinity

[Display Slide 10—Alkalinity Requirements for Nitrification.]

Alkalinity is another operating parameter that must be monitored. Typically, domestic wastewater contains enough alkalinity so that nitrification does not create pH problems; however, a minimum alkalinity concentration of 50 mg/L should be maintained. If the level falls below this, you may need to add alkalinity to the wastewater to maintain nitrification.

Students need to know how to do these calculations for certification.

Let's turn to the next page and take a look at how to calculate the amount of ammonia removed and the alkalinity requirement for complete nitrification.

[Review the first problem with the students on a flipchart then give them 10 to 15 min. to solve the second problem on their own.

[Display Slide 10—Alkalinity Checkpoint.] Answers will appear 'on'click'.

[Answer is in the answer key as well for the students.]

Temperature

[Display Slide 12—The Effect of Temperature on the Rate of Nitrification.]

This slide shows the relationship between temperature and the rate of nitrification. As you can see, as the temperature increases, the rate of nitrification increases.

[Review the information in the workbook.]

Dissolved Oxygen

Dissolved oxygen, or DO, is the next operating parameter we will review.

[Review the information in the workbook.]

Mean Cell Residence Time (MCRT)

Mean cell residence time, or MCRT, is another important operating parameter.

[Review the information in the workbook.]

Hydraulic Retention Time

The next parameter is hydraulic retention time.

[Review the definition of hydraulic retention time in the workbook.]

BOD$_5$/TKN Ratio

The BOD$_5$/TKN ratio is our next parameter. The higher the ratio, the lower the fraction of nitrifying bacteria present in the mixed liquor.

[Review the bulleted items in the workbook.]

Table 1.3 shows how the BOD$_5$/TKN ratio is related to the amount of nitrifying bacteria. Let's look at an example of how this correlates to the concentration of nitrifying bacteria in the mixed liquor of an activated sludge plant.
If your BOD$_5$/TKN ratio was 3.0, the fraction of nitrifiers, according to this table, would be equal to 0.083, or 8.3%.
If your MLVSS was 2,000 mg/l, to find the concentration of nitrifying bacteria, multiply the nitrifier fraction of 0.083 by the MLVSS, which is 2,000. By doing this, we get a nitrifying bacteria concentration of 166 mg/L.

[Write the following equation on a flipchart:]

MLVSS [conc] X Nitrifier fraction = Conc of nitrifying bacteria
2000 mg/l X 0.083 = 166 mg/l

[Review the remaining bullet item in the workbook.]

BOD:N:P Ratio

Our final operating parameter is the BOD:N:P ratio.

[Review the information in the workbook.]

BIOLOGICAL DENITRIFICATION: 35 minutes

Suspended Growth Reactors

As in biological nitrification, biological denitrification can occur using either suspended growth reactors or attached growth reactors. As with nitrification, we will only be discussing denitrification in suspended growth reactors.

[Review the information in the workbook including the definition for anoxic.]

Single Sludge Systems

[Review the information in the workbook.

Display Slide 13—Single and Separate Sludge Systems.]

Let's look at the single sludge post-denitrification diagram and the single sludge pre-denitrification diagram on this slide. As you can see, nitrification and BOD removal, noted as "NIT/DOB" and denitrification, noted as "DN" are occurring in the same basin. You will also see that there is only one sludge recycle stream, unlike the separate sludge post-denitrification diagram at the top of the slide, where you see two sludge recycle streams.

Post-denitrification Systems

[Continue to display Slide 13—Single and Separate Sludge Systems.]

Let’s talk about post-denitrification systems in more detail.

[Review the information in the workbook.]

Pre-denitrification Systems

[Continue to display Slide 13—Single and Separate Sludge Systems.]

Now let’s discuss pre-denitrification systems.

[Review the information in the workbook.]

Separate Sludge Systems

[Continue to display Slide 13—Single and Separate Sludge Systems.]

Now that we have discussed single sludge systems, we will turn our attention to separate sludge systems. Let's continue to look at slide 12 while we discuss separate sludge systems.

Operational Parameters

Next we will talk about the operational parameters that are important for denitrification.

[Review the information in the workbook.]

Temperature

Temperature is the first parameter we will discuss.

[Review the information in the workbook.]

[Display Slide 14—Checkpoint .]

Climates with large temperature variations can have a significant impact on denitrification. For example, the denitrification reactor volume at 10 °C would be about four times the volume required at 20 °C to achieve the same degree of nitrification. Why do you think this is the case?

[Write out answer on flipchart.]

Ans: T1 = 20 degrees C
T2 = 10 degrees C

$P = 0.25T^2$

$$\frac{P2}{P1} = \frac{0.25(T2)^2}{0.25(T1)^2} = \frac{0.25(10)^2}{0.25(20)^2} = \frac{25}{100} = 1/4$$

The denitrification rate at 10 degrees C is only 1/4 the rate at 20 degrees C and would, therefore, require 4 times the reactor volume to achieve the same degree of treatment.

[Display Slide 15—Single and Separate Sludge Systems.] and cover the remaining operational parameters in Unit 1.

Carbon Source

The next operational parameter is carbon source.

[Review the information in the workbook.]

Oxygen

Oxygen is the third parameter we will discuss.

[Review the information in the workbook.]

Mixing

Next we will highlight mixing requirements.

[Review the information in the workbook.]

Hydraulic Retention Time (HRT)

Hydraulic retention time is the next parameter.

[Review the information in the workbook.]

Sludge Age

Next we will talk about sludge age.

[Review the definition of sludge age in the workbook.]

Nitrogen Gas Separation Step

We will finish our discussion of operational parameters for suspended growth reactors for denitrification by discussing the nitrogen gas separation step.

[Review the information in the workbook.]

[Display Slide 16—Key points and Exercises.]

[Have the participants review the Key Points for Unit 1 – Nitrification and Denitrification.]

Give the students adequate time to complete the exercises and then review the answers with them and ask if there are any additional questions before proceeding to Unit 2.

☑ Exercise for Unit 1 – Nitrification and Denitrification

1. MCRT is the abbreviation for Mean Cell Residence Time .

2. The two types of aeration systems used in nitrification processes are surface aerators and diffusers.

3. The optimal pH range for biological nitrification is 7.2 to 9.0 .

4. Nitrification in the winter months may require up to five times the detention time used during the summer.

   [✓ a. True]   b. False

5. Single stage biological nitrification typically requires a MCRT of 8 to 20 days.

6. For biological nitrification to proceed efficiently, there must be an adequate supply of carbon, nitrogen, and phosphorous in the wastewater. If the phosphorus level is too low, it may be remedied by adding a phosphate fertilizer to the aeration tank.

   [✓ a. True]   b. False

7. In a denitrification process, it may be necessary to add a carbon source such as methanol if the total effluent nitrogen limit is less than 7.5 mg/L.

8. List the four types of suspended growth biological nitrification reactors that are commonly used.

   a. conventional or plug flow .

   b. complete mix .

   c. extended aeration .

   d. SBR .

We have now completed the first unit of this training module. You should have a good understanding of the various nitrogen removal mechanisms as well as an understanding of the nitrification and denitrification processes. In the next unit, we will talk about another nutrient, phosphorus, and how it is removed from wastewater.

[Point out that references are listed on this page.]

UNIT 2: 30 minutes

[Display Slide 17—Unit 2: Biological Phosphorus Removal.]

At the end of this unit, you should be able to:

- Explain what phosphorus is and why it needs to be removed from wastewater.
- List three forms of phosphorus.
- Explain the effect of phosphorus on receiving water.
- List three phosphorus removal mechanisms and explain how they work.

PHOSPHORUS OVERVIEW: 5 minutes

Like Nitrogen, phosphorus must be removed from wastewater. Phosphorus removal will be the focus of this unit.

What is Phosphorus?

[Review the information in the workbook.]

Three Forms of Phosphorus

Phosphorus in aqueous solutions typically comes in three forms: orthophosphate, polyphosphate and organically-bound phosphorus. Let's talk about those three forms now.

Orthophosphates

[Review the information in the workbook.]

Polyphosphate (P_2O_7)

[Review the information in the workbook.]

Organically Bound Phosphorus

[Review the information in the workbook.]

Effects of Phosphorus on Receiving Water

Since phosphorus is an algal nutrient, its effects on receiving waters are undesirable. Let’s talk about the effects of phosphorus on receiving water.

[Review the information in the workbook.]

PHOSPHORUS REMOVAL MECHANISMS: 25 minutes

Now that we understand the undesirable effects of phosphorus, let's talk about how to remove phosphorus. We will spend the remainder of our time in this unit reviewing three different phosphorus removal mechanisms: the A/O process, the PhoStrip Process and Flocculation and Precipitation. Let's start with the A/O process.

Biological Phosphorus Removal – A/O Process – Mainstream Treatment

[Review the defintion of the A/O Process in the workbook.

Review the information in the workbook. Make sure the students understand the environments needed for the PAO's for both uptake and release. NTK for certification.

Display Slide 18—The A/O Process.]

This slide shows a schematic of the A/O process.

[Review the information in the workbook.]

[Review the information in the workbook.

Display Slide 19—Design Information for the A/O Process.]

On this slide, we see some design information about the A/O Process. By referring to this table, we can see that the typical F/M ratio for the A/O process is 0.2 to 0.7. The typical value for MLSS is between 2,000 and 4,000 mg/L. The return activated sludge rate is usually 24% to 40% of the influent wastewater.

[Review the remaining bullet item in the workbook.]

Lime Precipitation –PhoStrip Process – Sidestream Treatment

The next phosphorus removal mechanism we will cover is the PhoStrip process.

[Review the information in the workbook.

Display Slide 20—The PhoStrip Process.]

This slide shows a schematic of the PhoStrip process. Let's take a look at how the process works.

[Review the information in the workbook and refer to slide 21 while reviewing the process.]

[Display Slide 21—Design Information for the PhoStrip Process.]

Let's take a look at this table again. This time, focus on the middle column, which shows design information for the PhoStrip process. The F/M ratio for this process is 0.1 to 0.5. The MLSS value is between 600 and 5,000 mg/L, which is a much larger range than the MLSS range for the A/O Process. The percent of return activated sludge for the PhoStrip process is between 20% and 50%.

[Review the information in the workbook.]

Aluminum Sulfate or Ferric Chloride Flocculation and Precipitation

As an alternative to biological treatment processes, the combined process of coagulation, flocculation and sedimentation can be used to remove phosphorus from wastewater. This will be the final phosphorus removal mechanism we discuss.

[Review the information in the workbook.

Display Slide 22—Chemicals Used for Phosphorus Removal.]

This slide shows where the metal salts and polymers used for phosphorus removal are used in various processes. The top of the diagram shows us that the metal salt, along with a polymer, is added before the primary clarifier. In the middle diagram, we see the metal salt and polymer added after the aeration basin, which is before the secondary clarifier. In the final diagram, the metal salt is added after the secondary clarifier instead of before it.

You will also find these diagrams in your workbook as we talk about each one of these techniques for using metal salts to remove phosphorus.

Phosphorus Removal Using Lime

Let’s talk about phosphorus removal using lime in more detail.

[Review the information in the workbook.]

The use of lime precipitation for phosphorus removal is declining due to the excessive quantities of sludge formed compared to metal salts and the difficulties in handling, storing and feeding lime.

Phosphorus Removal Using Metal Salts

Now let’s turn our attention to phosphorus removal using metal salts.

[Review the information in the workbook.]

Application dosages of metal salts and polymers vary depending on wastewater characteristics and should be determined from onsite jar testing.

Trickling filters and extended aeration plants often produce a secondary sludge that does not settle well. In these instances, the addition of metal salts and polymer, if needed, provides the dual benefit of greatly improving the sedimentation process and removing phosphates.

Display Slide 23—Key Points and Exercise.]

[Have the participants review the Key Points for Unit 2 – Biological Phosphorous Removal.]

Give the students adequate time to complete the exercises and then review the answers with them and ask if there are any additional questions before proceeding to Unit 3.

Exercise for Unit 2 – Biological Phosphorus Removal

1. List the three forms of phosphorus considered important for wastewater.

   a. Orthophosphates

   b. Polyphosphate (P_2O_7)

   c. Organically Bound Phosphorus

2. List four metal salts that can be used in treating water for phosphorus removal.

   a. Aluminum sulfate (or alum)

   b. Ferric chloride

   c. Ferric sulfate

   d. Ferrous sulfate

3. Using lime to remove phosphorus requires that the wastewater has a pH of about 11. After pH removal, carbon dioxide gas can be injected into the water to lower the pH.

4. How do the three phosphorus removal mechanisms differ?

[Allow a brief, 5 minute discussion of the differences between the various mechanisms.

Write participant responses on a flip chart.

Potential responses could be:]

The A/O process is a "mainstream" process where phosphorus is removed along the main plant flow stream (i.e., the secondary clarifier). The PhoStrip process removes phosphorus in a "sidestream" process (i.e., in the sidestream anaerobic stripper tank).

The A/O and PhoStrip processes are biological, whereas the flocculation and precipitation process is chemical.

The anaerobic and aerobic hydraulic retention times (HRT) for the PhoStrip process is longer than the corresponding HRTs for the A/O process.

[Point out that references are listed on this page.]

We have reached the end of Unit 2. You should understand why phosphorus needs to be removed from wastewater and you should be familiar with three means of removing it. In the next unit, we will talk about combined nitrogen and phosphorus removal.

[This page was intentionally left blank.]

UNIT 3: 45 minutes

[Display Slide 24—Unit 3: Biological Nutrient Removal (BNR).]

At the end of this unit, you should be able to:

- Explain how the A^2O process works.
- Explain how the Bardenpho process works.
- Explain how the process is controlled.

A^{2}O PROCESS: 15 minutes

In Unit 1, we discussed nitrogen removal. In Unit 2, we focused on phosphorus removal. In this unit, we will concentrate on combined nitrogen and phosphorus removal, or, biological nutrient removal. Specifically, we will learn about the A^{2}O process and the Bardenpho process. Let's begin with the A^{2}O process.

[Review the information in the workbook.

Display Slide 25—The A^{2}O Process.]

This slide shows the schematic of the A^{2}O process. You can see that this process is very similar to the A/O process we just discussed in Unit 2, however, an anoxic stage occurs after the anerobic stage.

[Review the information in the workbook.]

Table 3.1 shows design information for the combined biological processes. In the first column of the table, you will see the design parameters for the A^{2}O process. We will discuss these in detail later in this unit when we talk about process control.

[Review the remaining bullet item in the workbook.]

Let's talk about the three phases of the A^2O process and what happens in each phase.

[Continue to display Slide 25—The A^2O Process. This slide includes multiple processes. Be sure to refer to the schematic as you review each phase of the process.]

Phase 1: Anaerobic

[Review the information in the workbook.]

Phase 2: Anoxic

[Review the information in the workbook.]

Phase 3: Aerobic

[Review the information in the workbook.]

BARDENPHO PROCESS: <u>20 minutes</u>

Now we will discuss the Bardenpho process.

[Review the information in the workbook.

Display Slide 26—Five Stage Bardenpho Process. - This slide includes multiple processes. The Bardenpho is the second process on this slide.]

This slide shows the schematic for the Bardenpho process. As you can see, there are five stages in the process, as we just discussed. We will refer to this schematic as we review what occurs in each of the five stages.

Phase 1: Anaerobic

[Review the information in the workbook.]

Phase 2: Anoxic

[Review the information in the workbook.]

Phase 3: Aerobic

[Review the information in the workbook.]

Phase 4: Anoxic

[Review the information in the workbook.]

Phase 5: Aerobic

[Review the information in the workbook.]

[Review remaining information in the workbook.

Allow participants approximately five minutes to discuss the following:]

Explain the difference between the A^2O process and the Bardenpho process.

Ans: The A2O process is a three stage process consisting of an anaerobic stage, an anoxic stage and an aerobic stage. The Bardenpho process is a five stage process consisting of an anaerobic stage, then an anoxic stage, followed by an aerobic stage and then another anoxic and aerobic stage.

PROCESS CONTROL: 10 minutes

Display Slide 27 Typical Design Information for BNR .]

Now that we have learned about the two processes, let’s talk about how to control them. The parameters we will discuss are the MCRT, the RAS, the MLSS and recycle rate and the F/M ratio. Refer to Table 3.2 as we talk about the various parameters.

Mean Cell Residence Time (MCRT)

[Review the information in the workbook.]

Return Activated Sludge (RAS) Recycle Rate

[Review the information in the workbook.]

MLSS Concentration and Recycle Rate

[Review the information in the workbook.]

F/M Ratio

[Review the information in the workbook.]

Other Parameters

In addition to the parameters we just reviewed, there are a few additional parameters that are of significance to the BNR processes.

[Review the information in the workbook.

Display Slide 28—Optimum pH Levels.]

This slide shows the optimum pH Levels for different processes. For example, as we just discussed, pH below 7.2 inhibits nitrification. You can see this at the top, left side of this graph. We also see that once we go above a pH of approximately 8.5, nitrification is also inhibited. This is represented at the top right of the graph. You will also see on the top right of this graph that at a pH of approximately 9.5 and higher, inhibition of all treatment organisms is very likely due to the ammonia concentration at that pH.

Display Slide 29—Key Points and Exercise.]

[Have the participants review the Key Points for Unit 3 – Biological Nutrient Removal (BNR)]

Give the students adequate time to complete the exercises and then review the answers with them and ask if there are any additional questions before proceeding to Unit 4.

☑ Exercise for Unit 3 - Combined Nitrogen and Phosphorus Removal or Biological Nutrient Removal (BNR)

1. In the spaces below, write in the typical range of values for the indicated process control parameters:

   a. MCRT A^2O 4 – 27 days Bardenpho 10 – 40 days

   b. RAS recycle rate A^2O 20 – 50 % Bardenpho 50 – 100 %

   c. MLSS concentration A^2O 3000 – 5000 mg/L Bardenpho 2000 – 4000 mg/L

   d. F/M ratio A^2O 0.15-0.25 lb BOD / lbMLSSday

   Bardenpho 0.1-0.2 lb BOD / lbMLSSday

2. From the chart in Figure 3.3, determine the optimum pH range for the following processes:

   a. Aerobic treatment 6.5 – 8.3

   b. optimum for nitrifiers 7.5 – 8.2

   c. phosphorus removal by Al^{3+} addition 5.0 – 6.5

   d. phosphorus removal by Fe^{3+} addition 4.0 – 6.0

[Point out that references are listed on this page.]

Now that we have learned about combined nitrogen and phosphorus removal, we will move on to our final unit. In Unit 4 we will discuss treatment of combined municipal and industrial wastewater.

UNIT 4: 50 minutes

[Display Slide 30—Unit 4: Treatment of Combined Municipal and Industrial Wastewater.]

At the end of this unit, you should be able to:

- List some common industrial wastes and explain their effects on treatment plant performance.
- Describe the appropriate operational responses to a shock load.
- Explain the importance of recordkeeping and describe what types of records should be kept.

MONITORING PROGRAM AND PRETREATMENT REQUIREMENTS: 10 minutes

We will begin this unit by discussing some of the common types of industrial wastes that impact a wastewater treatment plant.

[Display Slide 31—Industrial Wastes.]

Industrial Wastes

[Review the information in the workbook.

Review the defintions of high strength waste and shock load in the workbook.]

High Strength

As we just learned from its definition, high strength waste is waste with a BOD_5 higher than 400 mg/L and a COD higher than 1,000 mg/L. Let's talk about where high strength waste originates.

[Review the first bullet item in the workbook.]

Metals and Solvents

Metals and solvents are another common industrial waste.

[Review the information in the workbook.]

Oils, Greases and Fuels

Oils, greases and fuels are common contaminants discharged from industrial sources.

[Review the information in the workbook.]

Fuels

[Review the information in the workbook.]

High/Low pH

[Review the information in the workbook.]

Other Toxic Materials

The list of potential materials discharged from industrial sources that are toxic to humans and activated sludge microorganisms is large due to a number of different industrial processes. Some of the more common toxic materials are fuels, toxic gases, amines, surface-active agents and biocides.

Toxic Gases

[Review the information in the workbook.]

Amines

[Review the information in the workbook.]

Surface-Active Agents

[Review the information in the workbook.]

Biocides

[Review the information in the workbook.]

Other substances toxic to activated sludge bacteria include chlorine, paints and chlorinated solvents. Classifications of and specific toxic substances are discussed in Module 16, Unit 2.

[Display Slide 32—High Strength Waste.]

In this section we will talk about how high strength waste impacts the performance of a wastewater treatment plant. Specifically, we will discuss the impact of high strength waste on DO, BOD and settling sludge.

High Strength Waste

Low DO

[Review the information in the workbook.]

High Effluent BOD

[Review the information in the workbook.]

Poor Settling Sludge

[Review the information in the workbook.]

Poor settling is covered in greater detail in “The Activated Sludge Process – Part II” training module.

[Display Slide 33—Metals.]

Metals

Metals, another type of industrial waste, also impact the performance of the treatment plant. Let's review their impact.

Toxicity

[Review the information in the workbook.]

MLSS Color Change

[Review the information in the workbook.]

High Effluent BOD/DO Problems

[Review the information in the workbook.]

Poor Settling Sludge

[Review the information in the workbook.]

[Display Slide 34—Oils and Greases.]

Oils and Greases

Oils and greases will also impact plant performance.

DO Problems

[Review the information in the workbook.]

Sheen on Water Surfaces

[Review the information in the workbook.]

Floating Grease Balls

[Review the information in the workbook.]

Odors

[Review the information in the workbook.]

Oils and greases are typically removed in aerated tanks outfitted with a surface skimmer.

[Display Slide 35—High/Low pH.]

High/Low pH

Just as high strength waste, metals and oils and greases affect plant performance, so does pH. Let’s talk about that in more detail.

Toxicity

[Review the information in the workbook.]

MLSS Color Change

[Review the information in the workbook.]

High Effluent BOD/DO Problems

[Review the information in the workbook.]

Poor Settling Sludge

[Review the information in the workbook.]

OPERATIONAL RESPONSES TO SHOCK LOAD: 23 minutes

[Display Slide 36—Operational Responses to Shock Loads.]

At the start of this unit, we talked about shock load, which is a slug of high strength waste. In this section of the unit, we will review the appropriate operational responses to a shock load.

Monitor DO and Aeration Rates

One operational response is to monitor DO and aeration rates in order to maintain a reasonable DO and prevent foaming.

[Review the information in the workbook.]

Check pH

Checking the pH is another operational response to a shock load.

[Review the information in the workbook.]

Adjust pH

Once the pH has been checked, it may be necessary to adjust the pH.

[Review the information in the workbook.]

Increase RAS Rates; Decrease WAS Rates

Increasing the RAS rates and decreasing the WAS rates is an important operational response.

[Be sure to review the key point in the workbook.

Review the remaining information in the workbook.]

Investigate Possible Sources

The final possible response to a shock load involves investigating sources.

[Review the information in the workbook.]

[Display Slide 37—Recordkeeping.]

RECORDKEEPING

Recordkeeping is an essential part of your role as a treatment plant operator.

[Review the information in the workbook.]

[Have the participants review the Key Points for Unit 4 – Treatment of Combined Municipal and Industrial Wastewater.]

☑ Exercise for Unit 4 - Treatment of Combined Municipal and Industrial Wastewater.

1. In the space below, write a short description of a plant upset that you have experienced or are familiar with. Explain what caused the upset and what steps were taken to return the plant to normal operation. Also, indicate any action taken to help insure that this kind of upset does not happen again.

We have now finished this module. You should be familiar with the various nitrogen removal and phosphorus removal mechanisms as well as combined nitrogen and phosphorus removal mechanisms. You should also understand the essential concepts involved in the treatment of combined municipal and industrial wastewater. Are there any questions about the material we covered in this module?